CHEM 2110 **TEST 3** **22 DECEMBER, 2011**

Chemistry for Medicine

Name: MODEL ANSWERS **ID Number:** ____________

Time: 2 hours

Useful constants: $N_A = 6.022 \times 10^{23}\ \text{mol}^{-1}$

$1\ \text{amu} = 1.6605 \times 10^{-24}\ \text{g}$

$1\ \text{atm} = 760\ \text{mmHg} = 760\ \text{torr}$

1 **H** 1.008																	2 **He** 4.003
3 **Li** 6.941	4 **Be** 9.012											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
11 **Na** 22.99	12 **Mg** 24.31											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.07	17 **Cl** 35.45	18 **Ar** 39.95
19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.88	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.69	29 **Cu** 63.55	30 **Zn** 65.38	31 **Ga** 69.72	32 **Ge** 72.59	33 **As** 74.92	34 **Se** 78.96	35 **Br** 79.90	36 **Kr** 83.80
37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.94	43 **Tc** (98)	44 **Ru** 101.1	45 **Rh** 102.9	46 **Pd** 106.4	47 **Ag** 107.9	48 **Cd** 112.4	49 **In** 114.8	50 **Sn** 118.7	51 **Sb** 121.8	52 **Te** 127.6	53 **I** 126.9	54 **Xe** 131.3
55 **Cs** 132.9	56 **Ba** 137.3	57 **La*** 138.9	72 **Hf** 178.5	73 **Ta** 180.9	74 **W** 183.9	75 **Re** 186.2	76 **Os** 190.2	77 **Ir** 192.2	78 **Pt** 195.1	79 **Au** 197.0	80 **Hg** 200.6	81 **Tl** 204.4	82 **Pb** 207.2	83 **Bi** 209.0	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** 226	89 **Ac†** (227)															

QUESTION	SCORE	MAXIMUM MARKS
1		
2		
TOTAL		

QUESTION 1

(a) A medical student was asked to determine the molarity of an aqueous solution of citric acid in the laboratory using a titration with sodium hydroxide. The molarity of the citric acid solution was known accurately to be **0.0560 mol/L**.

The student performed the experiment four times and obtained the following results:

0.0533 mol/L   0.0530 mol/L   0.0534 mol/L   0.0531 mol/L

(i) In the laboratory what glassware do we use to measure volumes of liquids in general?

pipette   volumetric flask

burette   graduated cylinder

(ii) The aqueous solution of citric acid was prepared from a crystalline solid of citric acid.

What are the different methods used to measure mass in the laboratory?

Weighing by taring

Weighing by difference

Name the two types of balances used to measure mass in the laboratory.

analytical balance   top-loading balance

(iii) Mass is an extensive property. What does this mean?

It means that it depends on the amount of the substance considered

Give two examples of an intensive property. density and temperature

(iv) **Discuss** the results of the determination of the molarity of citric acid above.

Since the measured values of the molarity are close to each other the measurements are precise or reproducible. The average value of the measurements is as follows:

$$\frac{\left(0.0533\,\frac{mol}{L} + 0.0530\,\frac{mol}{L} + 0.0534\,\frac{mol}{L} + 0.0531\,\frac{mol}{L}\right.}{4}$$

$$= 0.0532\ mol/L$$

$$\text{The \% error} = \frac{(0.0560 - 0.0532)}{0.0560} \times 100\% = \frac{0.0028}{0.0560} \times 100\%$$

$$= 5.0\ \%$$

The average value differs slightly from the actual (true) molarity. Thus the measurements are not very accurate, i.e. they are slightly accurate.

(v) Name the type of reaction that was used in the analysis of the citric acid solution.

acid-base reaction or neutralisation reaction

(b) Answer the following questions about **hemoglobin**.

(i) What is hemoglobin? An iron-binding protein that transports oxygen from the lungs to the body tissues via the blood circulatory system.

(ii) How many iron atoms are found in one molecule of hemoglobin?

Four (4) atoms

(iii) Hemoglobin is 0.3437% by mass of iron. Calculate the molecular mass of hemoglobin.

$$0.3437\% = \frac{4(55.85)}{M} \times 100\%$$

$$\therefore M = 6.500 \times 10^4 \text{ amu} = \text{molecular mass}$$

(iv) An average adult has 5.0 L of blood. Every milliliter (mL) of blood contains 5.0×10^9 red blood cells. Every red blood cell has an average of 2.8×10^8 molecules of hemoglobin.

Calculate the total mass of hemoglobin (in grams) in an adult.

$$5.0\text{ L} \times \frac{1\text{ mL}}{10^{-3}\text{ L}} \times \frac{5.0 \times 10^9 \text{ RBC}}{1\text{ mL}} \times \frac{2.8 \times 10^8 \text{ molecules of Hb}}{1\text{ RBC}}$$

$$= 7.0 \times 10^{21} \text{ Hb molecules}$$

$$n_{Hb} = \frac{N_{Hb}}{N_A} = \frac{7.0 \times 10^{21} \text{ Hb molecules}}{6.022 \times 10^{23} \text{ Hb molecules/mol}} = 0.011(6) \text{ mol}$$

$$\therefore m_{Hb} = n_{Hb} M_{Hb} = 0.011(6) \text{ mol} \times 6.500 \times 10^4 \text{ g/mol} = 750 \text{ g}$$

Determine the total mass of iron in the hemoglobin of an adult.

$$\text{Total mass of iron in Hb} = 0.3437\% \times 750 \text{ g}$$
$$= 2.6 \text{ g}$$

The mass of iron in hemoglobin is 65% of the total amount of iron in an adult. Calculate the total mass of iron in an adult.

$$65\% = \frac{m_{Fe(Hb)}}{m_{Fe(body)}} \times 100\%$$

$$65\% = \frac{2.6\,g}{m_{Fe(body)}} \times 100\% \quad \therefore m_{Fe(body)} = \underline{\underline{4.0}}\,g$$

(c) An unknown organic compound contains carbon, hydrogen and oxygen.

Complete combustion of **1.2010 g** of this compound gives **1.7604 g** of carbon dioxide. Complete combustion of **36.00 mg** of this compound produces **7.220 × 10^{20}** molecules of water.

(i) Determine the empirical formula of the unknown organic compound.

$$\underset{1.2010\,g}{C_xH_yO_z} + \text{excess } O_2 \longrightarrow CO_2(g) + H_2O(g)$$

$$1.7604\,g \Rightarrow m_C = \frac{12.01\,g}{44.01\,g} \times 1.7604\,g = 0.4804\,g$$

$$\therefore \%\,C \text{ in } C_xH_yO_z = \frac{0.4804\,g}{1.2010\,g} \times 100\% = 40.00\%$$

$$N_{H_2O} = 7.220 \times 10^{20} \text{ molecules}$$

$$\therefore n_{H_2O} = N/N_A = 1.199 \times 10^{-3}\,mol \Rightarrow \therefore m_{H_2O} = nM = 1.199 \times 10^{-3}\,mol \times 18.02\,g/mol = 0.02161\,g$$

$$\therefore m_H = \frac{2 \times 1.008\,g}{18.02\,g} \times 0.02161\,g = 2.418 \times 10^{-3}\,g = 2.418\,mg$$

$$\therefore \%\,H \text{ in } C_xH_yO_z = \frac{2.418\,mg}{36.00\,mg} \times 100\% = 6.717\%$$

$$\therefore \%\,O \text{ in } C_xH_yO_z = 100\% - (40.00\% + 6.717\%) = 53.28\%$$

C	H	O
$\frac{40.00\,g}{12.01\,g/mol}$	$\frac{6.717\,g}{1.008\,g/mol}$	$\frac{53.28\,g}{16.00\,g/mol}$
$\frac{3.331\,mol}{3.330\,mol}$	$\frac{6.664\,mol}{3.330\,mol}$	$\frac{3.330\,mol}{3.330\,mol}$
1.000	2.001	1.000

$\Rightarrow$ empirical formula = $\underline{\underline{CH_2O}}$

(ii) If three molecules of this compound contain 12 atoms of hydrogen, what is the molecular formula of this compound?

One molecule of $C_xH_yO_z$ contains $\frac{12}{3}$ atoms = 4 atoms

$\therefore$ Molecular formula = $C_xH_4O_z$

But since the empirical formula is CH_2O, the molecular formula is $\underline{C_2H_4O_2}$

(d) Write **reaction equations** for each of the following:

(i) The combustion of ethanol

$$C_2H_5OH(l) + 3O_2(g) \longrightarrow 2CO_2(g) + 3H_2O(g)$$

(ii) When aluminium is added to hydrobromic acid hydrogen gas is given off.

$$2Al(s) + 6HBr(aq) \longrightarrow 2AlBr_3(aq) + 3H_2(g)$$

(iii) The heating of a hydrated alkaline earth metal halide produces an anhydrous salt. (Alkaline earth metal = **M**, halogen = **X**)

$$MX_2 \cdot nH_2O(s) \xrightarrow{\Delta} MX_2(s) + nH_2O(g)$$

(iv) Mixing an aqueous solution of mercury(I) nitrate with an aqueous solution of ammonium phosphate produces a precipitate. (All salts of ammonium are soluble in water).

$$3Hg_2(NO_3)_2(aq) + 2(NH_4)_3PO_4(aq) \longrightarrow (Hg_2)_3(PO_4)_2(s) + 6NH_4NO_3(aq)$$

(v) Sublimation of carbon dioxide.

$$CO_2(s) \xrightarrow{\Delta} CO_2(g)$$

(vi) The oxidation of iron by oxygen gas produces a solid of iron(III) oxide as the only product.

$$4Fe(s) + 3O_2(g) \longrightarrow 2Fe_2O_3(s)$$

(vii) The reaction of formic acid with calcium hydrogen carbonate produces a colourless gas.

$$2HCOOH(aq) + Ca(HCO_3)_2(aq) \longrightarrow (HCOO)_2Ca(aq) + 2H_2O(l) + 2CO_2(g)$$

(viii) The reaction of tetraphosphorus decoxide with water forms phosphoric acid as the only product.

$$P_4O_{10}(s) + 6H_2O(l) \longrightarrow 4H_3PO_4(aq)$$

(ix) The hydronium ion and the hydroxide ion react in aqueous solution to produce water.

$$H_3O^+(aq) + OH^-(aq) \longrightarrow 2H_2O(l)$$

(x) The thermal dissociation of a molecule of iodine.

$$I_2(s) \xrightarrow{\Delta} 2I(g)$$

QUESTION 2

(a) Perform the following mathematical operations. Show all your calculations.

(i) 20 ºC = 2.9×10^2 K

or 290 K

$20 + 273.15 \Rightarrow$

$$\begin{array}{rl} & 2. \quad\quad\; \times 10^1 \\ + & 27.315 \times 10^1 \\ \hline & 29.315 \times 10^1 \end{array}$$

$\Rightarrow 29. \times 10^1$

$= 2.9 \times 10^2$

(ii) 646 torr = 0.850 atm

$$646 \text{ torr} \times \frac{1 \text{ atm}}{760 \text{ torr}} = 0.850 \text{ atm}$$

(iii) 9500 + 4500 = 1.40×10^4

$$\begin{array}{rl} & 9.5 \times 10^3 \\ + & 4.5 \times 10^3 \\ \hline & 14.0 \times 10^3 \end{array}$$

$\Rightarrow 1.40 \times 10^4$

(iv) 0.03036 cm ÷ 50.0 cm = 6.07×10^{-4}

$$\frac{0.03036 \text{ cm}}{y} = 6.07 \times 10^{-4}$$

$$\therefore y = \frac{0.03036 \text{ cm}}{6.07 \times 10^{-4}} = 50.0 \text{ cm}$$

(v) 0.039 dm^3 + 60.8 mL = 100. mL or 1.00×10^2 mL

$$0.039 \text{ dm}^3 \times \frac{L}{dm^3} \times \frac{mL}{10^{-3} L} = 39 \text{ mL}$$

$\therefore$

$$\begin{array}{rl} & 39 \quad\; mL \\ + & 60.8 \; mL \\ \hline & 99.8 \; mL \end{array}$$

100. mL

(vi) 9.9862×10^5 mg/dm^3 = 9.9862×10^2 OR 998.62 μg/μL

$$9.9862 \times 10^5 \frac{\cancel{mg}}{\cancel{dm^3}} \times \frac{10^{-3} \cancel{g}}{\cancel{mg}} \times \frac{\mu g}{10^{-6} \cancel{g}} \times \frac{\cancel{dm^3}}{\cancel{L}} \times \frac{10^{-6} \cancel{L}}{\mu L}$$

(b) Chlorine has two isotopes. One of these isotopes is ^{35}Cl with an atomic mass of 34.93 amu and a natural abundance of 75.53%.

Calculate the mass of the other isotope of chlorine in grams.

^{35}Cl 34.93 amu 75.53%

^{x}Cl m? $100\% - 75.53\% = 24.47\%$

$$\therefore \frac{75.53}{100}(34.93) + \frac{24.47}{100}(m) = 35.45$$

$$2638 + 24.47\,m = 3545$$

$$24.47\,m = 907$$

$$m = \frac{907}{24.47} = 37.1$$

∴ atomic mass of second isotope of Cl = 37.1 amu

$$\text{mass in grams} = 37.1\text{ amu} \times \frac{1.6605\times10^{-24}\text{ g}}{\text{amu}}$$

$$= 6.16\times10^{-23}\text{ g}$$

(c) Aluminium reacts with liquid bromine (Br_2) to produce solid aluminium bromide.

In an experiment, 40.75 g bromine was reacted with 5.56 g aluminium and 38.54 g aluminium bromide was obtained.

Calculate the percentage yield of aluminium bromide.

$$2Al(s) + 3Br_2(l) \longrightarrow 2AlBr_3(s)$$

$$\frac{5.56\text{ g}}{26.98\text{ g/mol}} \qquad \frac{40.75\text{ g}}{159.8\text{ g/mol}}$$

$n = 0.206$ mol $\qquad n = 0.2550$ mol

Al	Br_2
2 mol	3 mol
0.206 mol	x

$$\therefore x_{Br_2}\text{(required)} = \frac{3\text{ mol}}{2\text{ mol}} \times 0.206\text{ mol}$$

$$= 0.309\text{ mol (required)}$$

∴ 0.2550 mol is too little

Br_2 is the limiting reactant

Br_2	$AlBr_3$
3 mol	2 mol
0.2550 mol	x

$$\therefore x_{AlBr_3} = \frac{2\text{ mol}}{3\text{ mol}} \times 0.2550\text{ mol} = 0.1700\text{ mol}$$

theoretical yield of $AlBr_3$

$$= 0.1700\text{ mol} \times 266.6(8)\text{ g/mol}$$

$$= 45.34\text{ g}$$

∴ % yield of $AlBr_3$

$$= \frac{\text{actual yield}}{\text{theoretical yield}} \times 100\%$$

$$= \frac{38.54\text{ g}}{45.34\text{ g}} \times 100\%$$

$$= 85.00\%$$